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THE ELECTRIC BROODER

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FOREWORD

This bulletin is a contribution of the Division of Agricultural Engineering, University of California, and the Poultry Sub-Committee of the California Committee on the Relation of Electricity to Agriculture. It is the second of a series planned to report the results of investigations conducted jointly by the Agricultural Experiment Station, College of Agriculture, University of California, and the California Committee on the Relation of Electricity to Agriculture. This committee represents the agricultural and electrical industries in California that are working together for the purpose of making available reliable information concerning the use of electricity on the farm, and cooperating with similar committees in other states.*

E. D. MERRILL, Director,
California Agricultural Experiment Station.

* The personnel of this committee for 1926-27 is:

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THE ELECTRIC BROODER

B. D. MOSES¹ AND T. A. WOOD²

INTRODUCTION

“A brooder is a covered and warmed receptacle for the protection of chicks reared without a hen.” The heat required can be supplied by the combustion of fuel or by electricity. The universal demand for labor saving devices which are automatically controlled has resulted in the adoption by many farmers of brooders heated by electricity. Statistics indicate that at least five thousand of these units were in use in California in 1926.

In order to make this type of energy applicable to brooding, heat conservation is necessary. This has been effected in some cases by the use of heat insulation on the hover; in others by curtains around the outer edge of the hover; and again at other times by crowding chicks together, making use of the body heat. On account of poor ventilation and this crowding, losses have resulted which have sometimes been attributed to the use of electrically generated heat rather than to defects in brooder design and to improper manipulation.

The purpose of this bulletin is to report results of observations on brooders heated by electricity in actual field operation from the standpoint of general design, mechanical features, power requirements, and heating costs.

ELECTRIC BROODER REQUIREMENTS

In the profitable brooding of chicks certain essential requirements have to be met. Some of the more important are:

1. At least seven square inches of free floor space beneath the brooder should be provided for each chick.
2. Sufficient heat must be available to maintain a temperature of 90 to 95 degrees Fahrenheit two inches above the floor and five inches inside the outer edge of the hover under all weather conditions.

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² Field Engineer, California Committee on the Relation of Electricity to Agriculture.

3. The heating elements should be so arranged as to obtain a uniform distribution of heat and, if possible, to assist in ventilation.

4. A thermostat for temperature regulation should be provided.

5. Adequate ventilation is essential to introduce fresh air and to remove the excess carbon dioxide, water vapor, and other impurities as they are formed.

6. The brooder should be simple and well built. It should be so designed and constructed as to simplify operation, minimize costs and insure satisfactory brooding conditions.

7. The first cost as well as operating costs must be such as to render the use of the brooder profitable.

HEAT AND VENTILATION PRINCIPLES INVOLVED

The temperature of a body is due to the presence of heat in that body, and while there is but one kind of heat of which we have any knowledge, there are three known methods (convection, conduction, and radiation) by which this heat can be transferred from one body to another.

Convection is the transfer of heat from the source to the absorber by storing the heat temporarily in a carrier substance, such as air or water, and then bodily moving this substance from the source to the cooler heat absorber. For example, a living room is heated by a furnace in the basement. The heat is generated in the basement, is stored temporarily in the air above the furnace, and is allowed or caused to move by convection (air currents) to the living room.

Conduction is the transfer of heat from one small particle of a substance to the next, by contact of these particles or their near association, along the length or breadth of the substance. The fire in a stove, for instance, generates heat, which warms the inner surface of the stove metal. The particles on the inner surface of the metal pass this heat along to the next until the heat appears on the outside surface of the stove. The outside surface is not in contact with the heat source but is heated by conduction from a surface which is in direct contact. In gases and liquids, this action is comparatively slow, but in most metals it is much more rapid. The amount of heat transferred depends upon the difference in temperature between the inside and outside surfaces, the thickness of the substance through which it must pass, the area of this exposed surface, and the ability of the substance to transfer heat.

Radiation is the transfer of heat through space by means of vibrations in the ether.³ This is the most common type of heat transfer, since practically all heat upon the surface of this planet comes, or has come, directly or indirectly from the sun by radiation. Heat in this form is transferred with the speed of light, namely, 186,000 miles per second, and requires no material substance for this transfer. These vibrations or waves, do not become sensible heat, until they are absorbed by some substance such as the earth. The amount of heat transferred from the source to the absorber depends upon the size, nature, and surface temperature of the exposed radiating body, upon the distance through which the heat must be radiated, and upon the ability of the cooler body to absorb the heat vibrations.

Heat reflectors: Radiated heat, like light, can be reflected without great loss if proper reflecting surfaces are used. The amount of heat lost depends upon the surface condition of the reflector, upon the color of the reflector surface, and upon the substance of which it is made. Black, rough surfaces, for instance, will absorb practically all heat rays striking them, while a light polished metal surface may reflect 80 per cent of these rays. The direction of travel of reflected heat rays can be controlled by the use of concave, flat or convex reflectors. The sharpness or abruptness of the concentration or diffusion depends upon the radius of curvature of the reflector. By proper reflector designs then, radiated heat can be concentrated within a small area or can be diffused to almost any degree desired.

*Ventilation:*⁴ A brooder must be adequately ventilated, since water vapor, carbon dioxide, and other gases given off by the chick tend to accumulate beneath the hover when, for example, curtains are used or ventilation is otherwise more or less restricted. Water vapor has, in some instances, accumulated to such an extent as to result in high mortality to the chicks.

³ These vibrations or waves exist in nature in various forms. Sound, as an illustration, is transferred through matter by vibrations or waves in the substance surrounding or adjoining the sound source. Heat, light, and electricity require no such material substance for their transfer when in wave form, but are propagated instead with great speed through what appears to be empty space, but which is supposed by physicists to be filled with an immaterial, perfectly elastic, and weightless substance called ether.

⁴ "Ventilation consists in displacing vitiated air from an apartment and replacing it with fresh air." All the foul air is not displaced bodily at one time, but is diluted by the incoming fresh air until it is suitable for respiratory purposes. There are two methods of obtaining this ventilation, namely, by "natural" ventilation, in which the air movements are induced by a "thermal" head; and by "mechanical" ventilation, in which the air movements are maintained by a power-driven fan. All brooders tested used the natural system. However, in some cases the air flow was intensified by artificial heat which was installed at advantageous points in the system.

The ability of the brooder air to absorb this water vapor is limited by its temperature, volume, pressure, and humidity. Air which has absorbed all the water vapor possible is said to be "saturated" or to have a "relative humidity" of 100 per cent. If saturated air comes in contact with a surface cooler than this air, its temperature drops and its volume and water absorbing capacity decrease.⁵ This causes "condensation" and dew is formed upon the cooler surface.

Ventilation for the purpose of removing impure air and introducing fresh air affects both the amount of heat used and the quality of chick produced; but the *health of the chick should never be jeopardized in order to save a little heat*. The slight cost of the additional heat necessary to secure adequate ventilation is more than offset by the lower mortality of chicks and by the stronger chicks which are produced when all conditions are fully met.

ECONOMICS OF NEW DEVICES

Many devices are being developed to reduce brooding costs either by saving heat or by increasing the number of chicks that can be taken care of under the hover. These devices may be in the form of adequate heat insulation, a thermostat switch, or a different type of heating or ventilating system; and they may effect a saving by reducing the mortality, or by decreasing the amount of heat and of labor required. Before any new brooding device is purchased, the prospective customer should determine whether there really will be a saving effected by its use, since the additional money that can be economically invested in any device is limited by the returns which that device will earn.

NON-GLOWING (BLACK HEAT⁶) TYPES OF BROODERS STUDIED

The oldest type of electric brooder which seems to be economically successful, in so far as heating costs are concerned, consists of a rather low hover surrounded by curtains and heated by overhead non-

⁵ The ability of air to absorb water vapor is doubled for each 27 to 30° F rise in temperature and conversely is halved for each 27 to 30° F drop in temperature (within all practical limits of temperatures encountered). Air cannot sustain a humidity greater than 100 per cent. Should a drop in temperature occur to such air, enough vapor condenses out to establish equilibrium again.

⁶ "Black heat" is a term sometimes applied to the heat from electric heating elements, which operate at a temperature below the glow point; that is, the wire maintains its natural color (see fig. 21). "Convection" brooders are those in which this method of heat transfer predominates.

glowing heating elements (see figs. 1, 2, and sketch No. 1, fig. 3). These heating elements are fastened to the under side of the hover just above the heads of the chicks. The temperature of the air in the brooder is controlled, in so far as the electric heat used is concerned, by a thermostat switch. No definite provision has been made in this type of brooder to induce positive ventilation. When used with a relatively small number of chicks scattered over a large brooder floor area, this early form is fairly satisfactory.



Fig. 1.—A simple box type, non-glowing or convection electric brooder, using "overhead" heat. Note the use of good electric insulation, an ether wafer thermostat switch, and well designed power leads as well as the simplicity of the hover construction.

Sketch No. 2 (fig. 3) shows the usual hover employing overhead, non-glowing elements and fitted with a chimney and damper in the apex of the cone. Since warm air tends to rise, this method of connecting the confined brooder air with the room air, permits the heat generated by the heating elements to escape through the stack, even though the damper is but slightly open.

Sketch No. 3 (fig. 3) is a further modification of the chimney idea, using a stack which extends down into the brooder, and which may be of one piece or of the telescoping type. The telescoping stack can be adjusted until a place is reached where the temperature difference is

just enough to induce the proper ventilation of the brooder. This device prevents the waste of heat that may occur in the type just mentioned. It depends for its success upon manual control. Failure to adjust the stack for changing temperature and moisture conditions, however, is a source of trouble. The air flows in under the curtain at the edge and out through the stack, an arrangement which leaves the chicks which are near the curtain, in a cool draft.

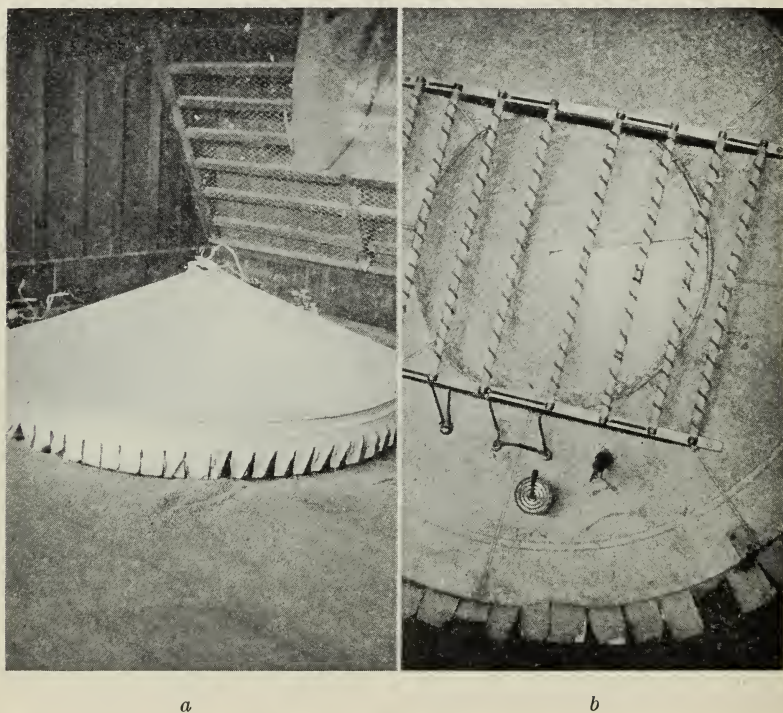


Fig. 2.—A conical galvanized iron non-glowing or convection type electric brooder, using overhead heat.

a. Side view showing the low, well constructed conical hover. This brooder can be placed under the dropping board or in other small compartments and allowed to rest on its own legs or it may be suspended from the ceiling by a hook at the apex of the cone.

b. A view from beneath, showing a good type of electric wiring. The heating elements are wound on asbestos sticks and are fastened to the hover by spring clips. Should the wire on one stick burn out it is easily removed and a new one snapped into place. Note that two heating circuits are connected in parallel, thus assuring some heat should one circuit burn out.

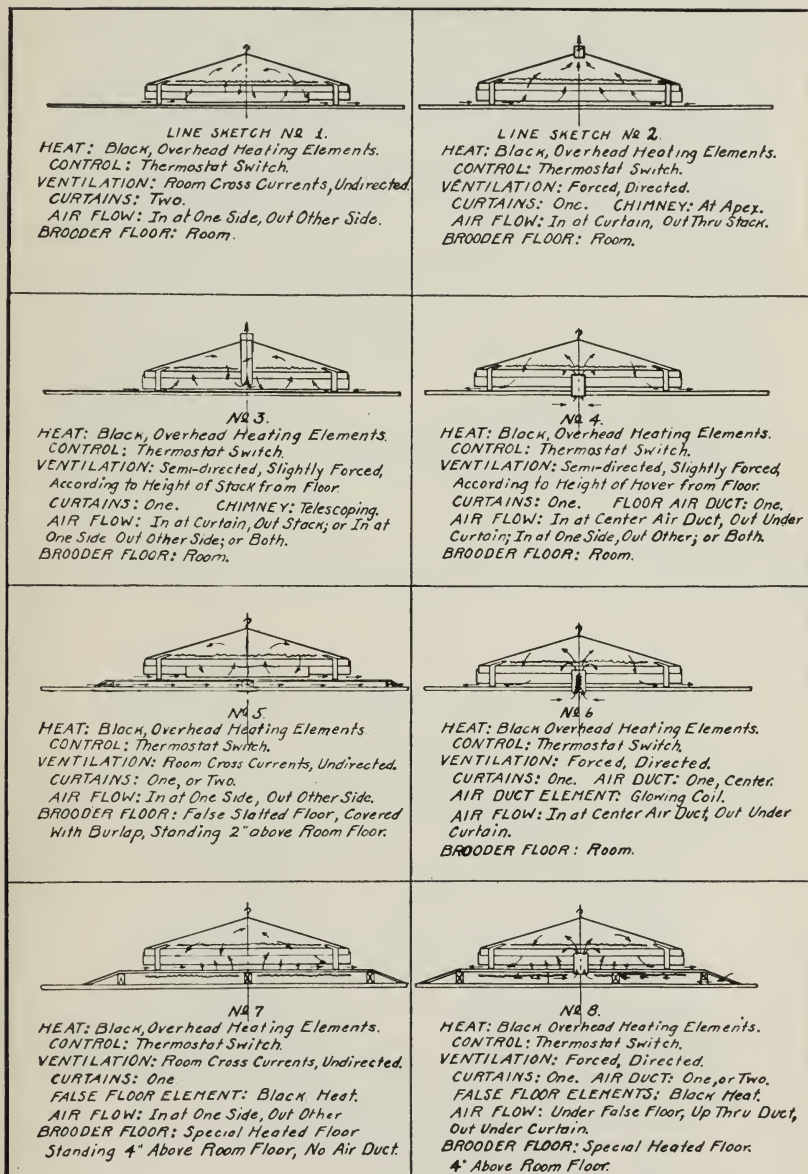


Fig. 3.—Line sketches of brooders studied.

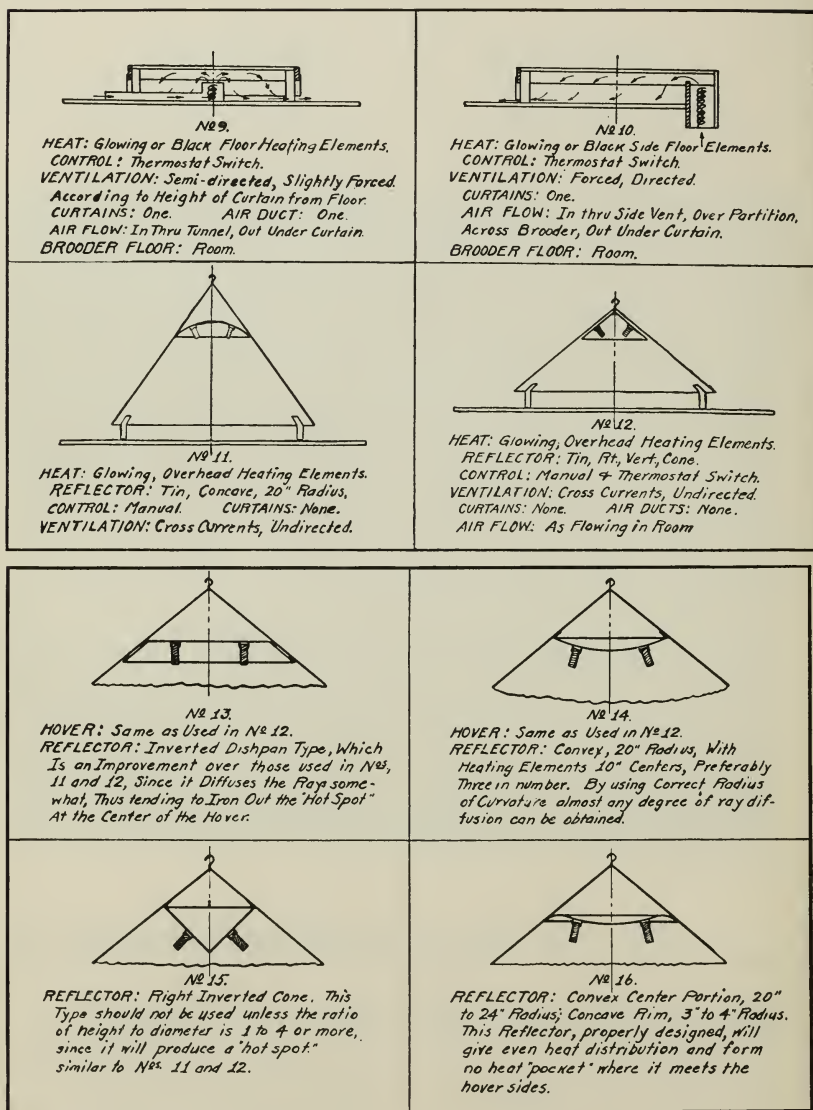


Fig. 4.—Continuation of series shown in figure 3.



Fig. 5.—A conical, galvanized iron, non-glowing or convection type electric brooder, using overhead heat and a chimney of fixed length. The counter balance at the top of the picture is used to adjust the height of the hover from the floor. Note that the curtain is several inches above the floor, thus allowing ample brooder ventilation.

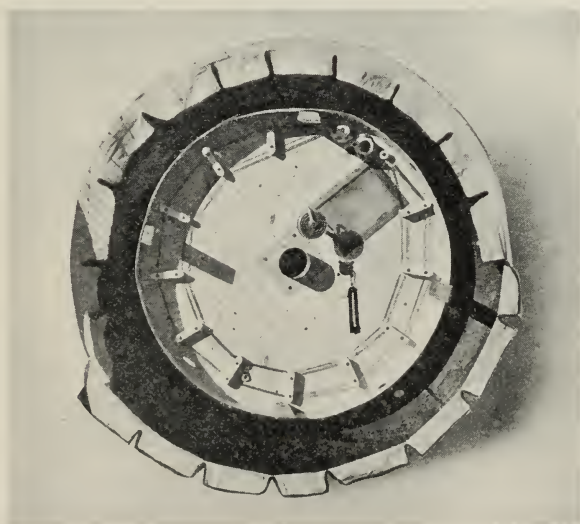


Fig. 6.—A non-glowing or convection type electric brooder, using overhead heat and a chimney of fixed length. Note the use of good electric wiring practices. The hover is well insulated against heat losses, especially in the central section.

Sketch No. 4 (fig. 3) shows the usual hover employing overhead non-glowing elements, with the addition of an air duct in the floor of the brooder. The purpose of this air duct is to permit an upward flow of fresh air through the floor into the brooder, thereby forcing impure air out under the curtain. This duct alone does not create a positive air flow and may or may not produce satisfactory ventilation. This type is shown in greater detail in figure 7.

Sketch No. 5 (fig. 3) shows the usual hover, employing overhead non-glowing elements and equipped with a false floor made of laths tacked to $1\frac{1}{2}$ inch by $3\frac{1}{2}$ inch joists and covered with burlap. The purpose of this false floor is to increase the effective drying surface, since the two sides of the burlap and the lath are exposed to the air flow; and to make possible the removal of some moisture by a change of burlap. The ventilation of the brooder is not affected to any noticeable degree.

Sketch No. 6 (fig. 3) shows a heating element installed in the brooder floor air duct to induce a positive, upward flow of fresh air into the brooder, thus forcing the impure air out under the curtain. This heating element is usually of the glowing type and operates at one-half its rated voltage or one-fourth of its rated watts. It is controlled by a separate snap switch and is on continuously. The main heat source is still the overhead, non-glowing type of unit shown in sketch No. 4, fig. 3. During the warm part of the day this overhead heat can be cut off and the air duct element left to supply all necessary heat to the chicks. Moisture troubles may develop only under adverse weather conditions, when feeding heavily of milk or when crowding is practiced. Moisture troubles, in this instance, may be due to inadequate ventilation or insufficient heat to supply the necessary heat of vaporization.

Sketch No. 7 (fig. 3) shows the usual hover employing overhead, non-glowing elements and equipped with a heated brooder floor but using no floor air duct. Heat is transferred by conduction from the lower to the upper surface of the floor, where convection currents are created, which tend to increase the air movements within the brooder. The use of a low hanging curtain restricts the air flow and prevents adequate brooder ventilation unless the hover is raised. The floor temperature did not exceed 80° F during the tests of this type of brooder.

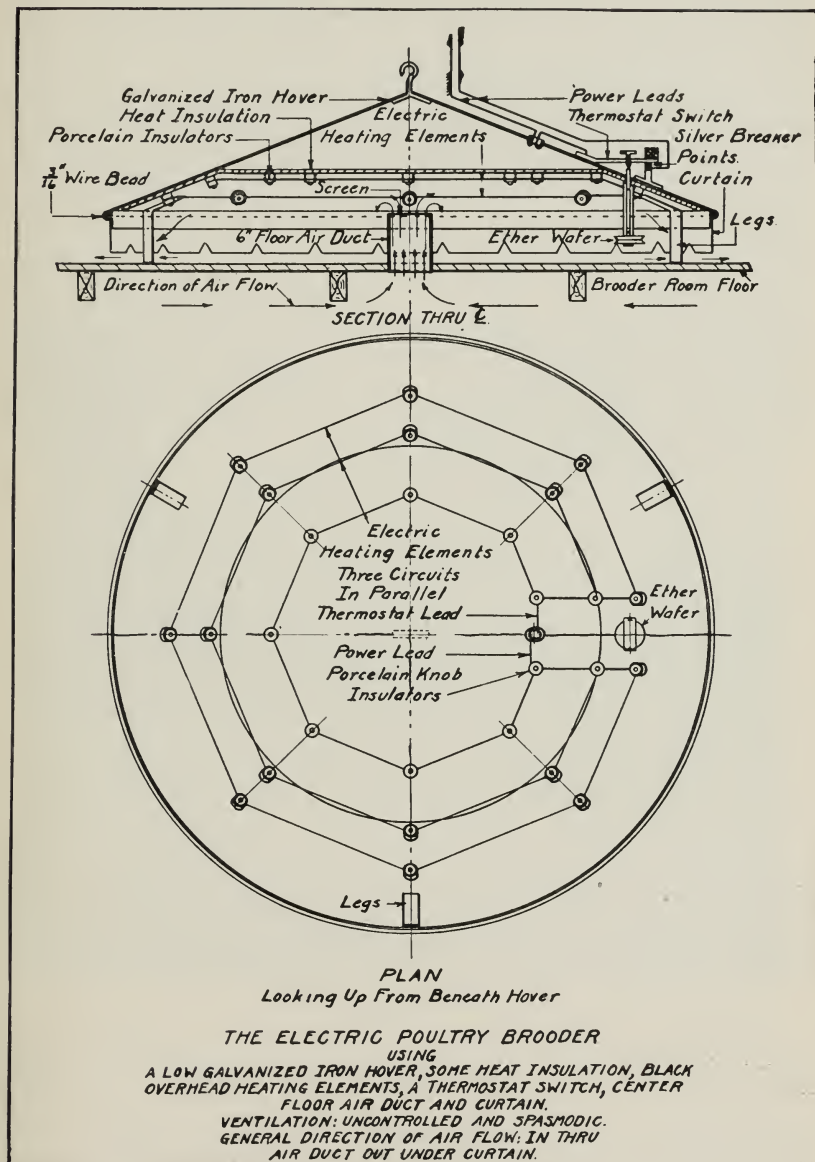


Fig. 7.—Detail of line sketch 4, figure 3.

Sketch 10 (fig. 4) shows a type which consists of a low flat box about ten inches high (outside measurement), closed on three sides, with a curtain in front. The heating elements are located in a separate side chamber. The heating chamber connects with the brooder room or outside air from below and with the brooder air from above, the convection currents being led up past the heating elements, over a partition, down across the brooder, and out under the curtain. The ventilation effect is quite positive because of the thermal head developed. From the standpoint of positive brooder ventilation, types 6, 8 and 10 have definite advantages.

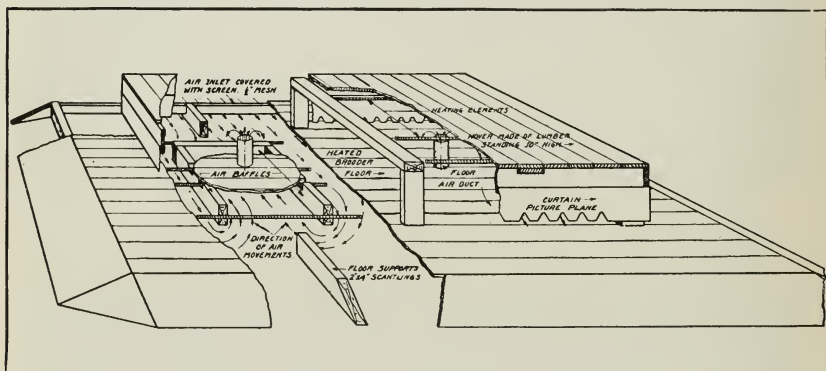


Fig. 10.—An electric brooder using black overhead heating elements, thermostat switch, floor air ducts, curtain, and heated brooder floor.

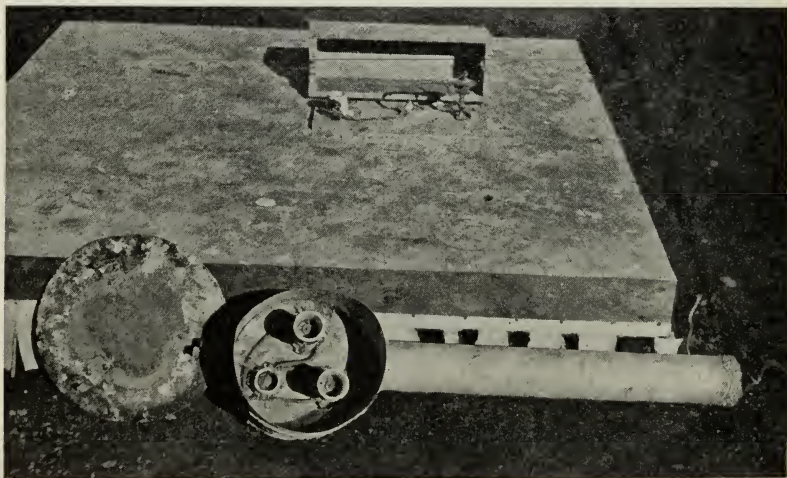


Fig. 11.—A simple, homemade, non-glowing or convection type of electric brooder. The hover resting upon its legs with heating compartment, fresh air duct, heating elements, and lid removed to show construction. The heating elements are in series each operating at one-third the rated voltage.

Other modifications in the convection type of brooder exist, which have not been described and for which no data were taken. As illustrations, figures 11, 12 and 13 are included.

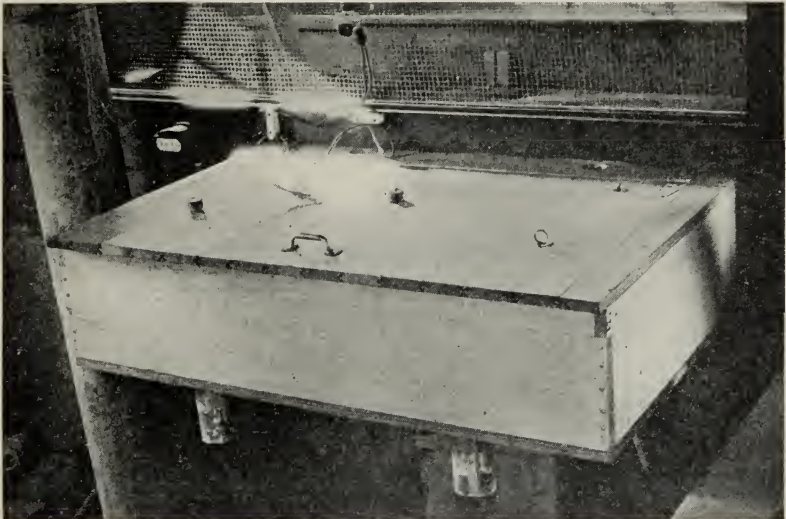


Fig. 12.—Back view of a homemade rectangular box type, convection, electric brooder. The brooder is closed on three sides with a curtain in front. The air enters the heating compartment through two air ducts (foreground, at lower edge), moves upward past heating elements, over a partition, and out under the curtain.

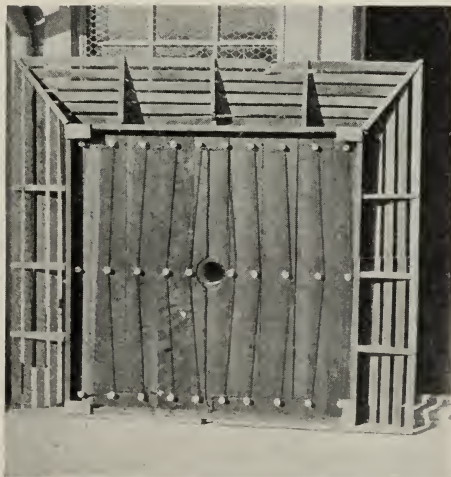


Fig. 13.—Bottom view of a homemade brooder floor sometimes used as an auxiliary to insure dry hover conditions.

SPECIFICATIONS OF NON-GLOWING (BLACK HEAT) ELECTRIC BROODERS

While the following list of parts does not include every item of which a brooder is made, it does include the essentials for the manufacture of an electric brooder of the "black heat," non-glowing, or convection type:

1. A rather flat *hover* to cover the chicks and help retain the heat. It can be made of galvanized iron, lumber, or other materials as desired, care being taken to select a material which will not be injured by the pecking of the chicks and which is easily cleaned and sprayed. If galvanized iron is selected, the hover should be conical in shape and should be about fifteen inches in height. It should have at least three legs about six inches long to support it and a hook at the top to suspend it when necessary. A $\frac{3}{16}$ -inch iron rod should be rolled into the outer edge to form a bead and give rigidity. If of wood, it can best be made square or rectangular in shape and should be about ten inches high. About seven square inches of floor space per chick should be allowed in designing a hover of any type. (See brooder computations, page 31 for chick capacity determinations.)

2. *Heat insulation* of the hover can be in the form of a suitable insulating material applied directly to the hover surfaces, or of a hover jacket filled with air or other insulating material. If the hover is constructed of metal, heat insulation is a very important item.

3. A *curtain* of cloth which will not ravel.

4. For electric insulators, *porcelain cleats* or *knobs* should be used every six or eight inches for fastening heating elements to the hover (never use uninsulated hooks or nails); *porcelain tubes* or *flexible asbestos tubing*, wherever electric wires pass through wood or metal; and *fiber board* or similar material under the thermostat and other switches.

5. A set of *electric heating elements*, preferably of the non-glowing type. (See table 2, page 32 for resistance wire sizes and lengths. Page 31 for sample brooder design.)

6. A *thermostat* switch in the electric circuit to turn heat on or off automatically as required. A good type of ether wafer or bimetallic thermostat is recommended.

7. A *pilot light* may or may not be included. Its only function is to indicate if the power is on or off and if the thermostat switch is working properly.

8. A good *ventilation system* to supply fresh air and to remove water vapor and other impurities from the brooder.

9. Necessary *rubber or asbestos-covered copper wire* of correct size for the load to be carried. (See page 33 for wire size calculations and table 1 for wire characteristics.)

Non-glowing or convection brooders were found in the field in various sizes. In the square or rectangular type they varied from 30 inches by 30 inches to 42 inches by 70 inches, and in the round type from 40 inches to 72 inches in diameter.

OPERATION OF NON-GLOWING BROODERS

The action of this type of brooder in its most common form is as follows: When the switch is closed the voltage of the electric system forces a current of electricity through the heating circuit. The heating elements in this circuit are made of a wire which offers considerable resistance to the current flow and heat is generated. The amount of heat generated varies directly as the product of the square of the current and the first power of the resistance or in symbols $H = K I^2 R$ where H is the heat generated, I the current flowing in amperes, R the resistance in ohms and K a constant, its value depending upon the system of heat units employed. The air within the brooder becomes heated by contact with the heating elements or by radiation from them, causing the air to expand and move upward and usually outward, while fresh and cooler air takes its place. As it moves away from the heating elements the air cools, contracts in volume, and gradually settles toward the floor. A part of this air in time passes out under the curtains and a part returns to the heating elements to repeat its journey. If the heat furnished is adequate and the air paths through the brooder are not too completely restricted, the resulting convection currents set up succeed in accomplishing brooder ventilation.

The temperature within the brooder continues to rise until the thermostat switch interrupts the circuit. When the air of the brooder cools again to a certain temperature, the thermostat switch closes and electric heating is resumed.

The use of curtains, insulation and thermostat switches all tend to reduce heating costs. Curtains, however, interfere with ventilation and when used some provision should be made to maintain adequate air replacement.

Every chick throws off water vapor from its lungs and in its feces, the amount depending first, upon its size or age, second, upon the kind of food, and third, upon the weather conditions. While the chicks are active about the brooder room and runway, the droppings are scattered so that their moisture content can be absorbed and removed by the room ventilation. However, at night when they enter the hover, the chicks concentrate within a small and often poorly ventilated space yet the amount of water given off by lung and feces and which must be dissipated remains practically the same. Curtains tend to prevent the dissipation of this moisture into the room or outside air and, as a result, the humidity of the brooder air may rise. The temperature of the hover tends to increase also because of the heat given off by the sleeping chick, and soon reaches a point at which the thermostat switch opens and the electric heat is cut off. With the heat cut off, ventilation is impaired, the air soon becomes saturated and a condition usually called "sweating" follows. "Sweating" on a chick's feathers or upon a window pane in a warm room is due solely to the condensation of water from the saturated warm air upon cooler surfaces. The condensation from the outside air upon the cooler roof of a house might have been called "sweating" instead of dew. The remedy for sweating then is adequate heat to cause the moisture deposits to vaporize and frequent enough brooder air changes to remove this vapor. Adequate ventilation or adequate heat alone cannot economically accomplish the result. The two must work together.

GLOWING OR "RADIANT"⁷ TYPES OF BROODERS STUDIED

Some brooders make use of the heat radiated from glowing wires to warm the space occupied by the chicks. They are usually conical in shape with the elements located near the apex. Heat reflectors are used to increase the effect of the heating elements, and some kind of insulating material is used on the surface of the metal of the hover to reduce heat loss to a minimum. (See sketches 11 and 12, fig. 4.)

⁷ Objects begin to glow, that is emit light which the eye is able to detect, at approximately 400° C (752° F). Up to the point at which they begin to glow they retain their natural color, which is due entirely to reflected light. The color first noted as metals begin to glow is a dull red, which gradually brightens as the temperature increases through blood red, cherry, bright red, salmon, orange, lemon, light yellow, and white. It should be remembered that this color is due to no chemical change in the metal but to the effect of the waves of the radiated light upon the eye.

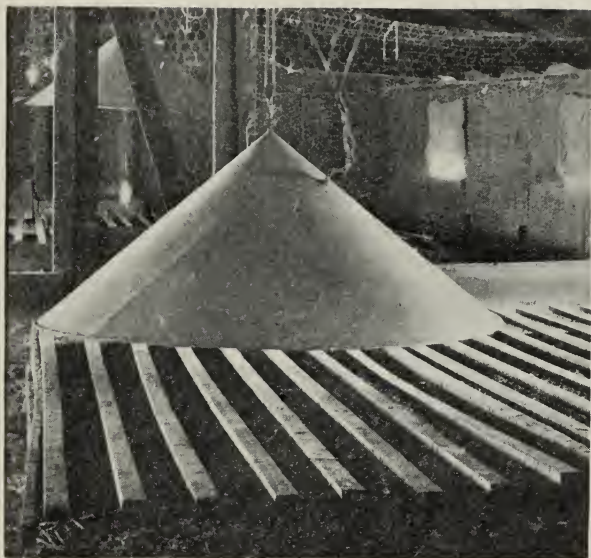


Fig. 14.—A conical galvanvanized iron “radiant” or glowing type of electric brooder, which uses glowing heating elements and a right vertical cone heat reflector. Note the absence of a curtain. The heating elements are located just below the heat reflector in the apex of the cone. By raising the hover slightly and placing the roosts in this heated area as shown, the chicks can be easily taught to go to roost.



Fig. 15.—A concave cone heat reflector sometimes used in “radiant” or glowing type brooders. A concave reflector concentrates the heat rays toward the center tending to create a “hot spot” on the floor.

The glowing elements used as the heat source in these brooders radiate heat outward in all directions. Since the chicks can be on the under side only, the heat radiating upward would be of no benefit to them if not reflected. The heat reflector, then, plays a very important part in this type of brooder. Concave and cone reflectors concentrate the rays toward the center, causing a "hot spot" to be formed on the brooder floor. By some, this is considered waste floor space, since the heat is too intense for the chicks to remain in this area. It has the virtue, however, of preventing center crowding and allows a warmer portion of the brooder for those chicks requiring more heat. Also, when a "hot spot" is used, a larger floor area may be available, since the heat may extend out beyond the confines of the hover, sometimes to a distance of eight or ten inches, and chicks have frequently been observed resting comfortably in this area.

The intensity and size of this "hot spot" can be controlled by the height of the reflector from the floor, by the radius of curvature of the reflector by lowering the wire surface temperature, or by screening the rays. Taking advantage of these principles, recent models have adopted improved types of heat reflectors (see heat reflectors, page 10), and at least a part of the heat is being controlled by a thermostat switch. Sketch 13 of figure 4 shows the usual radiant brooder equipped with a flat reflector. Since the angle at which the heat rays leave the reflector must equal the angle at which they strike, this reflector diffuses the rays to some extent. The temperature at the center of the hot spot is thus decreased slightly and its area increased, due to this diffusion.

Sketch 14 (fig. 4) shows the usual radiant brooder equipped with a convex heat reflector. A convex reflector of small radius diffuses the rays very rapidly, while one of greater radius diffuses to a less degree. The radius of curvature should not be less than 20 inches when a hover having a ratio of height to diameter of 1 to 2 is used.

Sketch 15 (fig. 4) shows the usual radiant brooder equipped with an inverted right cone reflector. With this reflector a good many of the heat rays must suffer double reflection, and some will be converted into heat before they reach the floor. If this type is used, the height of the reflector or cone should be about one-fifth of the reflector diameter. The resulting diffusion of the rays then approaches that of the convex reflector of large radius as described under No. 14. Since a cone is easily formed, this reflector will be very popular, but care should be taken to construct it with proper dimensions.



Fig. 16.—A conical, galvanized iron, “radiant” or glowing type of electric brooder, which uses radiant heating elements and a convex copper heat reflector. Note the heavy bead at the edge which gives the hover rigidity, short legs (not over three inches), thermostat switch and observation door on the side. The hover height should be about one-half the diameter.



Fig. 17.—A convex copper heat reflector such as that used in the radiant electric brooder. Two heating elements are on the thermostat circuit and two are controlled by a separate switch. This type of reflector diffuses the heat rays, making the complete area under the hover habitable by the chick.

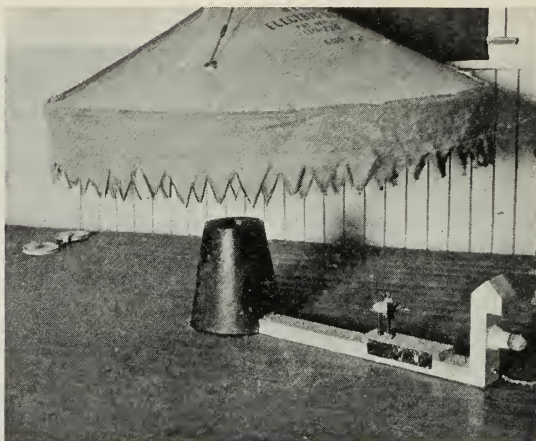


Fig. 18.—A conical, galvanized iron, “convection” and “radiant” brooder, using electric heat. The heating elements are cast in concrete and have taps for 110 or 220-volt service. The concrete block is hollow at the center and this hollow center compartment is connected to the room air by an air duct at the bottom. The air in the center compartment becomes heated and rises, while new and cooler air takes its place via the duct. The concrete when heated radiates heat into the brooder. It therefore combines the characteristics of both the convection and the radiant brooders.

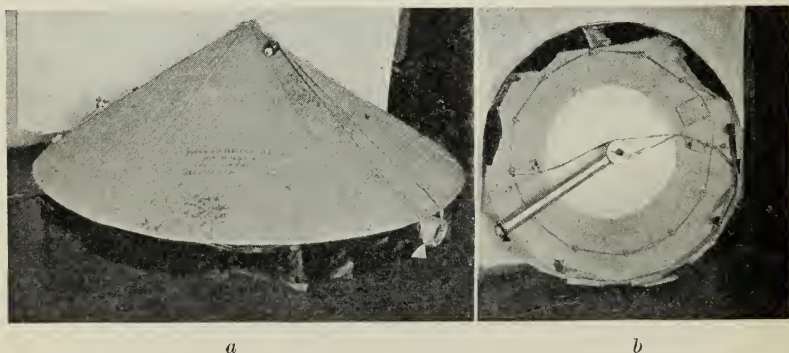


Fig. 19.—A conical, galvanized iron, convection type of hover, which uses combination top and center heat.

a. The hover resting upon its legs, with the center intake opening of the air duct showing at the right.

b. The hover resting on its side showing the center heating compartment, air duct, reflector, top heating circuit, porcelain knob insulators, and ether wafer thermostat. Some heat is radiated from this center compartment into the brooder and some is reflected downward from the reflector above.

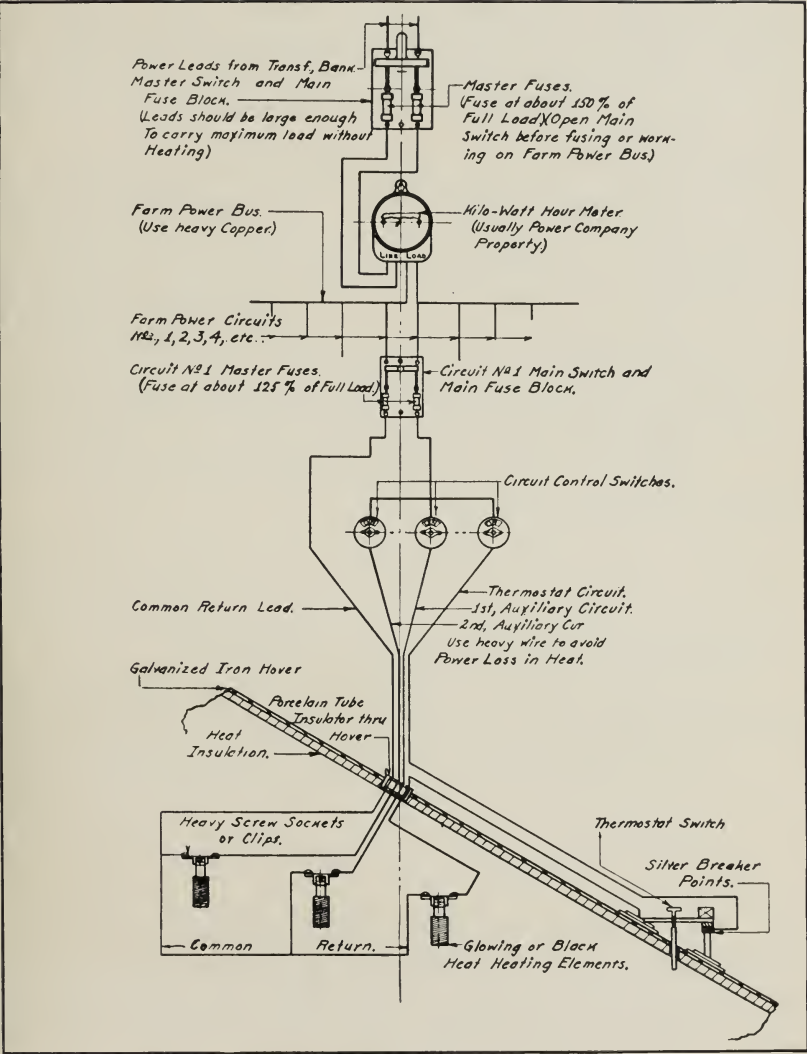


Fig. 20.—Electric wiring diagram of a typical farm power layout showing an electric brooder connected to one of the available power circuits.

The reflector should be made of some metal which will not curl or warp when subjected to the heat from the elements. Tin does very well and when it tarnishes can be given a coat of high heat-resistant aluminum paint. This paint costs very little and increases the reflector efficiency to approximately 80 per cent. Copper, brass, zinc, or other metals can be used but are more expensive. Galvanized iron should not be used since the heat causes the zinc coating to peel off after a short time.

Sketch 16 (fig. 4) shows a radiant brooder equipped with a combination convex and concave reflector. The center portion diffuses the heat rays and the concave rim prevents the formation of a radiation heat pocket, where the reflector meets the hover sides. It should be remembered in the construction of this reflector that for best results the hover sides should meet the concave rim at a tangent and that no seams, wrinkles or rough spots should exist on the reflecting surface. A hover $2\frac{1}{2}$ feet by 5 feet would require a convex reflector about 20 inches in diameter located 26 inches above the floor. If the surface has a curvature of approximately 26 inches the heat rays will be reflected uniformly to the floor.

SPECIFICATIONS OF GLOWING OR RADIANT TYPE BROODERS

The main parts to the glowing type of brooder are:

1. A conical, galvanized iron *hover* to cover the chicks and help retain the artificial heat. It should have a hook at the top to suspend it, at least three legs (about three inches long) to support it, and a $\frac{3}{16}$ -inch rod rolled into the edge to form a bead and to give rigidity. Short legs are specified so as to permit the lowering of the hover while the chicks are young or when power fails. The ratio of hover height to diameter should be about 1 to 2.

2. A *heat reflector*, preferably that shown under sketch No. 16 (fig. 4) with dimensions approximately as listed on page 22.

3. Adequate *heat insulation* of the hover. This may be applied directly to the hover surfaces, or may consist of a hover jacket filled with air or other insulating material.

4. Electric *insulators* for wiring and fixtures. *Porcelain tubes* or *bushings* should be used wherever the wires pass through the hover metal; *porcelain base*, *screw sockets*, or *insulated clips*, where the elements are attached to the reflector and *fiber board* or similar material under the thermostat switch and other switches.

5. *Electric service connections.* Screw sockets or spring connector clips should be used that will carry at least twenty amperes without heating.

6. *Glowing type of electric heating elements.* Two or more units should be used with a total wattage equal to the brooder demand. (For brooder calculations see page 31 and for resistance wire size and length, see table 2.)

7. A *thermostat switch*, preferably of the expanding ether wafer or bimetallic type for temperature control, to be connected into one of the heating circuits. (Not all the circuits.) See figure 20.

8. *Separate wall switches* for each heater circuit. (Three heating elements will require three wall switches in addition to the thermostat switch, for ease in control.)

9. Necessary *rubber covered copper wire* to bring the power from the supply mains to the hover. It should be of correct size for the load to be carried. (For wire size calculations, see pages 33 and 35, and for wire characteristics, see table 1.)

10. Necessary *asbestos covered copper wire* to connect the heating elements under the hover to the rubber covered leads above the hover. Asbestos covered leads should be used wherever the wires are subjected to the hover heat.

“Radiant” brooders were found in various sizes, from 42 to 72 inches in diameter. There is no reason why smaller units could not be used but heating costs per-chick-season increase as the number of chicks per brooder decreases. Again, as in the convection brooder, the five-foot size was the one found to be most commonly used.

OPERATION OF GLOWING TYPE BROODERS

As in the non-glowing brooder, the heat in the glowing type is developed by an electric current flowing through heating elements, the length, size, and material of which are such as to cause them to glow. The main heat transfer is by radiation but a slight convection effect results where the air comes in direct contact with the heating elements.

That portion of the heat which is generated on the under side of the heating element is radiated directly to the floor, but all heat appearing on the upper side must be reflected. This amounts to approximately one-half of the total heat. It does not become useful until the rays are absorbed by the chicks, the floor, or the hover walls.

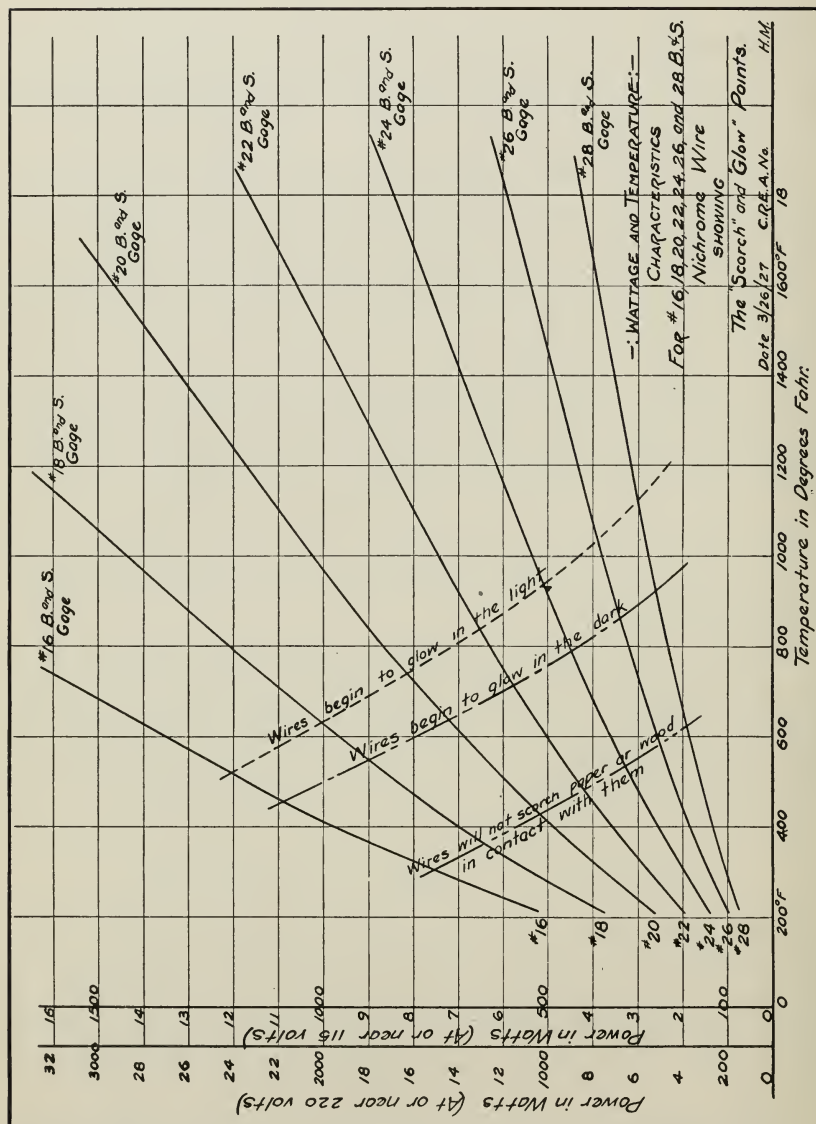


Fig. 21.—Temperature characteristics of Nichrome wire, showing "scorch" and "glow" points.

When the temperature beneath the hover rises to a certain point, the thermostat opens one circuit of the heating system. Should the temperature continue to rise, a wall switch on one of the other heating circuits may be opened or the heat allowed to find its own balance, while the chicks, if necessary, move further out. The radiant heat applied directly to the floor causes any moisture deposits to evaporate into the air and pass from the hover into the room air, there being no curtain to restrict the flow. This automatic removal of moisture by the radiant, curtainless brooder is an important advantage when used by inexperienced poultrymen. Tests indicate that with proper heat control sufficient heat can be obtained to effect proper ventilation and drying without excessive additional cost. No harmful effects upon the chicks from the light of the glowing elements have been reported or observed.

COMBINATION CONVECTION AND RADIANT BROODERS

Combinations of the various types of brooders previously described have resulted in units employing both types of heat transfer. This seems to be a logical development, since such a brooder may be able to incorporate most of the advantages of both types and still remove some of their disadvantages. By using both glowing and non-glowing elements as an illustration, the radiant element could be smaller than is now possible, while the thermostat could be installed in the non-glowing circuit thus furnishing a heat "safety factor" and removing the objection that radiant elements burn out when subjected to thermostatic action.

ELECTRIC BROODER WIRING PRACTICE

The following suggestions will be found helpful in the construction of an electric brooder and its connection to the power leads:

1. *The wire* should be of the correct size and should be properly insulated for the load to be carried and the temperatures encountered. (For wire sizes and current carrying capacities, see table 1.)

2. *The heating elements* should develop the proper amount of heat and should be made of high grade resistance wire. (For resistance wire, sizes and lengths necessary to develop specified power, see table 4.)

3. *The brooder power circuit* should be properly protected by fuses. (Fuses should not be used with a rating greater than 125 per cent of full load.)

4. *The thermostat switch* should be of sturdy construction and positive in operation. The breaker points should be of silver and not less than three-sixteenths of an inch in diameter to avoid burning. A condenser across the breaker points reduces the intensity of the arc.

5. *The service connections* (sockets or spring clips) should be heavy enough to carry the current at the temperature encountered. This is very important on account of the high air temperatures in which they may operate.

6. *All poor contacts*, such as loose screws, poorly spliced wires, and badly formed eyes, must be avoided.

7. *Porcelain* or other good insulators should be used at frequent intervals beneath the hover and where the leads pass through the hover material. (Uninsulated hooks or nails should never be used to suspend the elements from the hover.)

8. Only high grade electrical materials should be used.

TABLE 1

TABLE GIVING RESISTANCE, WEIGHT, CURRENT CARRYING CAPACITY, AND VOLTAGE DROP FOR RUBBER COVERED AND WEATHERPROOF COPPER WIRE

Wire size B & S gage*	Resistance per 1000 ft. at 68° F., or 20° C	Rubber covered copper wire				Weatherproof copper wire			
		Weight per 1000 ft. including wire and insulation	Feet of wire per pound	Maximum safe current carrying capacity in amperes*	Voltage drop in leads per 100-foot lengths for maximum current†	Weight per 1000 ft. including wire and insulation	Feet of wire per pound	Maximum safe current carrying capacity in amperes*	Voltage drop in leads per 100-foot lengths for maximum current†
18	6.385	14	71.4	3	1.92	16	62.4	5	3.19
16	4.015	18	55.5	6	2.41	20	50.0	10	4.01
14	2.525	30	33.3	15	3.79	25	40.0	20	5.05
12	1.588	41	24.4	20	3.18	35	28.6	25	3.97
10	.9989	55	18.2	25	2.50	53	18.9	30	3.00
8	.6282	76	13.1	35	2.20	75	13.3	50	3.14
6	.3951	134	7.5	50	1.98	112	8.9	70	2.77
5	.3133	190	5.3	55	1.72	135	7.4	80	2.51
4	.2485	220	4.5	70	1.74	164	6.1	90	2.24
3	.1970	270	3.7	80	1.57	199	5.0	100	1.97
2	.1563	320	3.1	90	1.41	260	3.8	125	1.95
1	.1239	365	2.7	100	1.24	316	3.2	150	1.86
0	.0983	495	2.0	125	1.23	407	2.5	200	1.97
00	.0779	600	1.7	150	1.17	502	2.0	225	1.75
000	.0618	760	1.3	175	1.08	629	1.6	275	1.70
0000	.0490	925	1.1	225	1.10	767	1.3	325	1.59

*From 1925 Electrical Safety Orders, Industrial Accident Commission, State of California, pages 26-27.

†The wire length required is twice the distance in feet. Thus, 15 amperes carried 50 feet to a load will require 100 feet of No. 14 wire and will cause a voltage drop of 3.79 volts.

COMPUTATIONS ON THE SELECTION AND DESIGN OF AN ELECTRIC BROODER

In order to illustrate the method of computing hover size and wiring specifications let it be required to design a "radiant" or glowing type electric brooder of 500-chick⁸ capacity, to operate on a 110-volt electric circuit. Allowing 7 sq. in. of floor space per chick, then—

Free *area* under hover = $500 \times 7 = 3500$ sq. in. or 24.3 sq. ft.

If the hover is to be circular its diameter can be found from the formula $D = \sqrt{\frac{4 \text{ Area}}{3.1416}}$. The *diameter* then = $\sqrt{\frac{4 \times 24.3}{3.1416}} = 5.56$ feet. But if the hover is to be square the length of one side can be found from the formula—length of side = $\sqrt{A} = \sqrt{24.3} = 4.93$ feet.

The size of the heating elements should next be determined and assuming 2.5 watts per chick, the total *wattage* of the *heating elements* = $500 \times 2.5 = 1250$ watts.⁹

Let it be assumed now that three separate circuits are to be used. The power for each circuit would be $1250 \div 3 = 416$ watts, and by applying the formula for single phase non-inductive electric circuits, Watts = Volts $\times$ Amperes, the current through each heating element is found to be $\text{Current} = \frac{416}{110} = 3.78$ amperes.

Now by referring to table 2 it will be found that No. 27 nickel chrome wire will have a surface temperature of approximately 1472° F when carrying 3.44 amperes and by referring to figure 21 it will be seen that No. 28 wire, slightly smaller than No. 27, begins to glow at about 1150 degrees F.

⁸ The Poultry Husbandry Division of the University of California recommends that not more than 300 chicks be placed in any brooder at one time. This design is carried through for a brooder of 500-chick capacity because it illustrates design features better and because the average brood found in the field during these tests was slightly above this figure.

⁹ One thousand watts of electrical power applied for one hour will produce a heating effect equal to approximately 3412 British thermal units (B.t.u.) or 860.5 kilogram-calories (kg-cal.). Therefore, 1 watt-hour will produce 3.412 B.t.u. or .8605 kilogram-calories. A 600-watt element operating for one hour will then produce $600 \times 3.412 \text{ B.t.u.} = 2047.2 \text{ B.t.u.}$, or $600 \times .8605 \text{ kg-cal.} = 516.3 \text{ kilogram-calories}$. 1 B.t.u. is equivalent to .252 kilogram-calories and 1 kilogram-calorie is equivalent to 3.965 B.t.u. The kilogram-calorie is generally defined as the amount of heat required to raise one kilogram of water from 14.5° C to 15.5° C. The British thermal unit is that quantity of heat used in raising the temperature of one pound of water from 62° F to 63° F.

After selecting the wire to be used it is next necessary to determine the length. This can be found by knowing that the Length required = $\frac{\text{Total Resistance}}{\text{Resistance per foot}}$. Table 2 gives the resistance of No. 27 wire as 3.274 ohms per foot at 68° F or 3.274×1.1122 (resistance factor, see table 3) = 3.6413 ohms per foot at 1472° F.

It is also known that Volts = Amperes $\times$ Resistance and in this case the voltage = 110 and amperage = 3.79. Therefore

$$\text{Resistance} = \frac{110}{3.79} = 29 \text{ ohms and the Length of Wire} = \frac{29}{3.6413} = 7.97 \text{ feet.}$$

The safe carrying capacities of various size wires are given in table 1 and the computations for the service wires are similar to those for the heating elements.

TABLE 2

RESISTANCE, CURRENT, AND TEMPERATURE CHARACTERISTICS OF "NICHROME"
RESISTANCE WIRE, WITH SPECIFIC RESISTANCE OF 600 OHMS.†
PER CIRCULAR MIL FOOT AT 68° F (20° C)

Wire size B. & S. gage	Diameter of wire in inches	Resistance in ohms per foot at 68° F. 20° C.	Current in amperes necessary to produce the temperatures listed below for straight wire in air, in a horizontal position									
			212° F. 100° C.	392° F. 200° C.	572° F. 300° C.	752° F. 400° C.	932° F. 500° C.	1112° F. 600° C.	1292° F. 700° C.	1472° F. 800° C.	1652° F. 900° C.	
No. 10	.102	.063	12.3	22.4	30.6	38.0	44.8	51.2	57.0	63.1	68.8	
No. 12	.081	.100	8.80	16.1	22.0	27.3	32.1	36.8	40.8	45.3	49.4	
No. 14	.064	.161	6.31	11.5	15.8	19.6	23.0	26.2	29.3	32.4	35.5	
No. 16	.051	.254	4.54	8.28	11.35	14.1	16.5	18.9	21.0	23.4	25.6	
No. 18	.040	.412	3.26	5.95	8.13	10.1	11.8	13.6	15.1	16.8	18.4	
No. 20	.032	.645	2.32	4.27	5.83	7.30	8.53	9.70	10.85	12.0	13.2	
No. 21	.0285	.813	1.97	3.62	4.94	6.17	7.23	8.21	9.20	10.2	11.2	
No. 22	.0254	1.031	1.67	3.07	4.18	5.23	6.13	6.96	7.80	8.65	9.46	
No. 23	.0226	1.292	1.42	2.60	3.54	4.43	5.19	5.90	6.61	7.33	8.02	
No. 24	.0201	1.634	1.20	2.20	3.00	3.75	4.40	5.00	5.60	6.20	6.80	
No. 25	.0179	2.060	1.02	1.86	2.54	3.18	3.73	4.25	4.67	5.27	5.76	
No. 26	.0159	2.611	.865	1.58	2.15	2.70	3.16	3.61	3.96	4.47	4.88	
No. 27	.0142	3.274	.734	1.34	1.82	2.28	2.68	3.06	3.36	3.80	4.13	
No. 28	.0126	4.159	.622	1.13	1.54	1.85	2.27	2.62	2.86	3.23	3.50	
No. 29	.0113	5.168	.527	.960	1.305	1.57	1.93	2.22	2.45	2.71	2.97	
No. 30	.0100	6.600	.447	.814	1.105	1.33	1.64	1.89	2.08	2.30	2.52	
No. 31	.0089	8.333	.378	.680	.935	1.13	1.39	1.60	1.77	1.95	2.14	
No. 32	.0080	10.313	.321	.577	.791	.955	1.18	1.36	1.50	1.66	1.81	
No. 33	.0071	13.098	.272	.490	.670	.809	1.00	1.15	1.28	1.41	1.53	
No. 34	.0063	16.623	.231	.416	.567	.685	.849	.980	1.06	1.18	1.29	
No. 35	.0056	21.019	.196	.353	.480	.580	.720	.830	.90	1.00	1.09	
No. 36	.0050	26.400	.166	.300	.406	.491	.611	.704	.765	.850	.924	
No. 37	.0045	32.672	.141	.254	.344	.416	.518	.597	.650	.721	.783	
No. 38	.0040	41.240	.120	.216	.291	.352	.440	.507	.552	.613	.663	
No. 39	.0035	54.098	.101	.183	.246	.298	.373	.430	.467	.517	.566	
No. 40	.0031	73.333	.085	.155	.208	.252	.316	.364	.396	.439	.480	

Adapted from tables by Driver-Harris Company, Detroit, Michigan.

†If a wire of different specific resistance is used, see illustrative problem, page 33, for correct lengths.

TABLE 3

“COLOR-TEMPERATURE” CHART FOR METALS AND “TEMPERATURE CORRECTION FACTOR” FOR “NICHROME” RESISTANCE WIRE AT TEMPERATURES ABOVE 68° F. AN APPROXIMATE “COLOR-TEMPERATURE” CHART FOR ALL METALS.

Part “A”

Color of metal	Black or natural	Faint red	Blood red	Cherry red	Bright red	Salmon red	Orange	Lemon	Light yellow	White
Approximate temperature.....	Zero to 800° F	800° F to 1050° F	1050° F to 1150° F	1150° F to 1300° F	1300° F to 1600° F	1600° F to 1700° F	1700° F to 1800° F	1800° F to 1950° F	1950° F to 2050° F	2050° F and up

“TEMPERATURE CORRECTION FACTOR”† FOR THE RESISTANCE WIRE USED IN THESE TABLES. SPECIFIC RESISTANCE 660 OHMS PER CIRCULAR MIL FOOT AT 68° F, 20° C. FOR STRAIGHT WIRE IN A HORIZONTAL POSITION IN AIR.

Part “B”

Wire surface temperature.....	68° F	212° F	392° F	572° F	752° F	932° F	1112° F	1292° F	1472° F	1652° F	1832° F
	20° C	100° C	200° C	300° C	400° C	500° C	600° C	700° C	800° C	900° C	1000° C
Resistance correction factor....	1.0000	1.0185	1.0417	1.0645	1.0828	1.0928	1.0960	1.1022	1.1122	1.1257	1.1423

Adapted from tables published by the Driver-Harris Company, Detroit, Michigan.

†Illustration on use of “Part B” of Table 3:

Resistance per foot of No. 25 resistance wire at 68° F., 20° C. is 2.060 ohms. (Table 2.)

What is the resistance per foot of this wire at 1472° F., 800° C.?

Under 1472° F., (800° C.) above, find 1.1122 (Correction factor).

Therefore, resistance per foot of No. 25 resistance wire at 1472° F. (800° C.) is $2.060 \times 1.1122 = 2.2911$ ohms.

Total watts to be delivered by the service wires to each brooder = 1250 watts.

Current flowing to each brooder = $\frac{1250}{110} = 11.36$ amperes and from

table 1 it is seen that No. 16 rubber covered wire will carry 6 amperes safely and No. 14 will carry 15 amperes. It is better to be amply safe so No. 14 should be chosen.

If a wire of different specific resistance than that of table 2 is used, its length can be obtained by multiplying the above length (7.97) by 660 and dividing by the new specific resistance; or, as an illustration, if the specific resistance per circular mil foot is 750 instead of 660 ohms, the correct length is obtained by multiplying the old length, 7.97, by $\frac{660}{750} = 7.02$ feet. (This is not an exact solution but for practical computations will be found entirely satisfactory.)

By similar computations, the length of wire necessary to produce this amount of heat in non-glowing heating elements can be determined. (For non-glowing computations the temperature assumed should be approximately 572° F and should not exceed 800° F.) Table 4 lists results of computations on both non-glowing and glowing heat designs and may be used in the design of brooder heating elements without going through the above computations.

TABLE 4

RESISTANCE WIRE SIZES AND LENGTHS TO PRODUCE "BLACK HEAT" AND GLOWING SURFACE TEMPERATURES WHEN CONSUMING KNOWN WATTAGES AT 110 VOLTS. FOR "NICHROME" RESISTANCE WIRE OF 660 OHMS SPECIFIC RESISTANCE.

Part "A"—Wire Surface Temperature: About 572° F, Non-Glowing

Required wattage....	100	200	250	300	350	400	450	500	550	600	650
Amperes at 110 volts	.909	1.818	2.27	2.727	3.180	3.636	4.09	4.545	5.00	5.454	5.91
Resistance in ohms.	121.01	60.51	48.40	40.33	34.60	30.25	26.85	24.19	22.00	20.17	18.62
Size of wire, B & S gage from Current-temperature chart	31	27	25	24	23	22	22	21	21	20	20
Resistance of wire at 68° F, ohms.....	8.333	3.274	2.060	1.634	1.292	1.031	1.031	.813	.813	.645	.645
Resistance of wire at 572° F ohms.....	8.870	3.485	2.195	1.739	1.375	1.099	1.099	.865	.865	.687	.687
Element length in feet, at 572° F.....	13.64	17.36	22.10	23.19	25.14	27.55	24.50	27.96	25.45	29.35	27.10

Part "B"—Wire Surface Temperature about 1472° F; "Radiant Heat," Glowing

Required wattage....	100	200	250	300	350	400	450	500	550	600	650
Size of wire, B & S gage, Current-temperature chart.....	35	31	30	29	28	27	26	26	25	25	24
Resistance of wire at 68° F, ohms.....	21.019	8.333	6.600	5.168	4.159	3.274	2.611	2.611	2.060	2.060	1.634
Resistance of wire at 1472° F, ohms.....	23.373	9.263	7.34	5.747	4.62	3.641	2.903	2.903	2.291	2.291	1.819
Element length in feet.....	5.17	6.54	6.59	7.02	7.49	8.31	9.25	8.34	9.59	8.80	10.24

NOTE.—Non-glowing wire smaller than No. 25 gage is too fine for successful operation in brooders. "Radiant heat" wire, smaller than No. 29, is also impractical for brooder use. Therefore, wattages under 250 are impractical, unless long wire is used or the wire is of extremely high resistance.

VOLTAGE DROP

When an electric current flows through a conductor, a drop in voltage occurs along the wire in the direction of flow. This drop in voltage is analogous to the drop in pressure which occurs along a pipe carrying water from a tank or pump. Should this stream of water

be shut off, the pressure in the pipe immediately rises to a value equal to the static head of the system. In a similar manner, when an electric current is interrupted the pressure or voltage across the *live* terminals of the switch immediately rises to a value equal to the voltage of the system.

This drop in voltage when a current flows should be kept as low as is economically possible, since it indicates that heat is being developed in the conductor and dissipated into the atmosphere where it can do no good. Usually a voltage drop in excess of 5 per cent will prove uneconomical.

To illustrate the extent of this loss when long leads are used, it was found during one test that 81.8 amperes were being carried from the meter to the poultry house, a distance of 400 feet, by No. 2 weather proof copper wire. The total length of wire necessary then to carry the current to the brooders and back again will be 2 times 400 feet or 800 feet. The resistance of No. 2 copper wire at 68° F is (from table 1) .1563 ohms per 1000 feet. The resistance of 800 feet is .8 times .1563 or .1250 ohms. The power lost as heat in the conductor was the current in amperes squared times the resistance, or $81.8 \times 81.8 \times .1250$ or 836.4 watts. If this current flows 24 hours a day for the three months of the brooding season, the loss will be 836.4 (watts per hour) times 24 (hours per day) times 90 (days) or 1,806.6 kilowatt-hours. At 2 cents per kilowatt-hour this represents a loss of 2×1806.6 , or \$36.13. The drop in voltage from meter to load was 836.4 watts divided by 81.8 amperes or 10.2 volts.

Assume now a voltage drop not greater than 5 per cent in the power leads from this meter to the load, which on the 110-volt circuit will give 110 (volts) times 5 (per cent) or 5.5 volts drop. The power now converted into heat in these leads will be 5.5 (volts) times 81.8 (amperes) or 449.9 watts. During the three months of the brooding season, this will amount to 971.8 kilowatt-hours or, at 2 cents per kw-hr., \$19.44. The conductor required for a 5 per cent drop in 800 feet when 81.8 amperes are flowing will have a resistance of $\frac{449.9 \text{ (watts)}}{81.8 \times 81.8}$ (amperes) or .0672 ohms. A thousand feet of this conductor will have a resistance of $\frac{.0672}{.8}$ or .0840 ohms. From table 1 the wire having a resistance nearest to this figure is No. 00, which has a resistance of .0779 ohms per 1000 feet. Therefore, if a voltage drop not to exceed 5 per cent is to be allowed, the conductor used should be *No. 00 weatherproof copper wire*.

It should be remembered that this loss in power due to a voltage drop occurs only when a current is flowing through the wire. There is practically no loss when the line is not being used.

The larger wire will cost considerably more to install, since the same length (800 feet) weighs almost twice as much. Will it be economically sound to make this additional investment in the power leads?

The weight of No. 2 weatherproof copper wire required for the 800 feet, according to table 1 is $260 \times .8$ or 208 pounds, while the weight of No. 00 is $502 \times .8$ or 401.6 pounds. The *extra copper* then which must be purchased if No. 00 is used is 401.6 minus 208 or 193.6 pounds. The cost per pound of this wire will average 25 cents. The *additional investment in the line*, due to heavier wire, will be 193.6 (pounds) times 25 (cents per pounds) or \$48.40.

Applying the reasoning set forth under Economics of New Devices, page 6, the following figures result:

	As installed	If correctly installed
Additional copper costs 193.6 lbs. at 25 cents per pound.....		\$48.40
Additional interest at 6 per cent of one-half value.....		\$1.45
Yearly additional depreciation (10-year life)		\$4.84
Repairs, taxes, insurance and overhead, same for both		
Loss due to line resistance	\$36.13	\$19.44
	\$36.13	\$25.73
Savings affected by use of larger copper		\$10.40

If the transformer bank had been centrally located with respect to the load, as is often possible, a considerable saving in the cost of the wire would have resulted. For best results, the meter should not be more than 200 feet from where the power is being absorbed.

SAFETY PRECAUTIONS

In working with any electrical circuit, it is well to remember the following:

1. Never attempt to work with a "hot" or live circuit. Open the circuit switch or remove the circuit fuses first. While 110 volts will seldom injure one, there are conditions under which it may be injurious.

2. Consider all electric wires "hot" unless you have opened the circuit yourself or know it to be open.

3. If a shock is received from the ordinary electrical appliances, determine the cause at once. It generally indicates poor electrical insulation.

4. Never work with a power circuit when standing on wet ground or wet floors, or when in water.

5. Never allow the body to become a part of a circuit. The body can form a circuit either to "ground" or to the opposite power "leg."

6. Always remember that both legs of an alternating current circuit as usually operated are "live."

7. Fuse the circuits on both legs and fuse for about 125 per cent of full load. These fuses will protect your electrical apparatus and the circuit.

SUMMARY AND CONCLUSIONS

The electric brooder is heated with electric heating elements and makes use of radiation, convection or conduction for transferring heat from the elements to the space occupied by the chick.

When radiation is depended upon as the method of heat transfer and the elements are operated at glowing temperature, the hover is generally three to four feet high, no curtains are used and little or no trouble will be experienced from "sweating." The heating cost at 2 cents per kilowatt-hour will average about 2.5 to 3 cents per chick each 1000 hours.

For mild climates 2 watts should be allowed per chick and where freezing temperatures are experienced 2.5 to 3 watts should be available.

Because of the high temperature of the elements there is a slightly greater fire hazard than is found in the "black heat" type.

In brooders using radiation but equipped with elements that do not glow the hover is low, usually has curtains, and has some special provision for taking care of air replacement. Operation costs are somewhat lower than with the "glowing" type. The heaters should have a capacity of from 1.5 to 2 watts per chick.

The brooders depending upon convection usually heat some or all of the incoming air, may or may not use curtains, may use either the glowing or non-glowing elements, are comparatively free from sweating troubles, and cost from $\frac{3}{4}$ of a cent to 1 cent per chick for each 1000 hours to heat.

Due to the tendency of the moisture to condense on the chick's feathers under certain conditions the removal of the tainted air is of prime importance in all types. Some brooders have provision for positive ventilation, others have not. The open or curtainless type of hover requires more heat than the closed or curtain type but it has better ventilation.

Seven square inches is the brooder floor area recommended per chick. If a smaller space is used less heat will be required but ventilation troubles will probably be greater. The chief difference between brooders lies in the comparative cost and dependability of operation. Those that conserve the heat by means of curtains, crowding or restricted ventilators will cost less but will be less satisfactory than those less careful of the heat but more careful of ventilation.

In general, brooders using non-glowing coils also use curtains while those using glowing elements do not.

Table 6 follows, which is a condensed summary of the results of tests conducted by the California Committee on the Relation of Electricity to Agriculture during this investigation.

TABLE 6

CONDENSED SUMMARY ELECTRIC POULTRY BROODER TESTS, ALL TYPES 1925, 1926,
CONDUCTED BY THE CALIFORNIA COMMITTEE ON THE RELATION OF
ELECTRICITY TO AGRICULTURE

	Non-glowing Brooder tests.	"Radiant" or glowing type brooder tests
Total number of test farms.....	8	6
Total number tests run.....	33	16
Total chicks under test.....	21940	10994
Total chicks finished.....	18121	9532
Total mortality.....	3819	1462
Total kilowatt-hours consumed.....	8596.9	14810.0
Average brood.....	665	687
Average mortality, per cent.....	17.4	13.3
Average kilowatt-hour "per-chick-season".....	.474	1.553
Average connected load per chick, watts.....	1.298	1.908
Average brooding season, hours.....	974	1200
Average brooder area, square inches.....	4.88	7.83
Average cost per chick, (2 cents per kw.-hr. base).....	.948 cents	3.110 cents

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